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OBSERVATIONS OF PULSARS, PSR 1509 – 58 AND PSR 1259 – 63, BY CANGAROO 3.8 m TELESCOPE

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ABSTRACT

The data for VHE (\sim TeV) gamma rays from young gamma-ray pulsar PSR1509-58 observed in 1996 with the CANGAROO 3.8m Čerenkov imaging telescope are presented, as well as the additional data from March to June of 1997. The high spin-down luminosity of the pulsar and the plerionic feature around the pulsar observed with radio and X-rays suggest that VHE gamma-ray emission is quite likely above the sensitivity of the CANGAROO telescope. The CANGAROO results on other pulsars, such as PSR1259-63, are also presented. PSR1259-63 is a highly eccentric X-ray binary system, which includes a high mass Be companion star, and a preliminary analysis on the data taken 4 months after the periastron in 1994 suggests emission of VHE gamma rays.

INTRODUCTION

Extensive efforts have been made for detecting VHE gamma rays from galactic objects which are considered to be VHE gamma ray emitters such as pulsars, supernova remnants and EGRET sources. The Crab, PSR B1706-44 and the Vela pulsars are found to be VHE gamma ray sources by using imaging Čerenkov telescope, and, as these examples indicate, a young rotation-powered pulsar is a likely accelerator of non-thermal energetic particles. A shock mechanism may occur between the pulsar wind and circumstellar matter to form a pulsar nebula, where particle acceleration and/or randomization of the pulsar wind flow of relativistic particles takes place. Non-thermal phenomena have been seen by radio and X-ray synchrotron emission, but more direct evidence for the existence of the relativistic electrons in such nebulae can be given by the

VHE gamma ray radiation of inverse Compton effect. In order to model the emission through the wide spectrum range, more detailed studies are needed to reveal the nature of the pulsar wind and particle acceleration, by comparing the VHE phenomena of many pulsars with each other.

Radio pulsars of short periods have been also long studied in VHE gamma ray astronomy. The binary pulsar PSR B1259-63 with 47.8 ms period is unique, because of its strong magnetic field, i.e., not a recycled pulsar, and also the fact that it changes from radio pulsar to X-ray emitter near the periastron of binary orbital motion. Intense stellar wind from the companion Be star presumably collides with the pulsar wind to generate a shock in the binary system.

In this paper, we present the latest results of CANGAROO on the two objects; PSR B1259-63, and PSR B1509-58 which is a composite system of pulsar, nebula and supernova remnant.

CANGAROO

CANGAROO has confirmed the VHE gamma-ray emission from PSR1706-44 (Kifune et al. 1995), and also from Crab at $>7\text{TeV}$ (Tanimori et al. 1994). Evidence of gamma-ray signals has also been detected from the direction of the Vela Pulsar (Yoshikoshi, 1996). All of three are the known gamma-ray pulsars detected by the EGRET experiment. Another EGRET pulsar, which is in a good position for the CANGAROO observation, PSR1055-52 does not show the VHE gamma-ray emission above the CANGAROO sensitivity. Not only the survey for the EGRET pulsars, CANGAROO is also observing many categories of targets. Supernova remnant is one of the most interesting candidates. We have performed observations of W28 and SN1006. And PSR1509-58 can be associated with SNR MSH15-52. These objects are probably extended compared with the typical spacial resolution of the present VHE gamma-ray detectors (0.1deg). Using the fine resolution of the CANGAROO camera, the analysis for such extended sources has been developed, and Vela is thought to be possibly extended rather than point-like. About SNRs, the data of SN1006 taken in 1996 indicates a VHE gamma-ray emission and it is probably extended. Observation is continuing in 1997 to confirm this indication.

The CANGAROO 3.8m telescope is located at Woomera, South Australia ($136\text{E}, 31\text{S}, 160\text{m a.s.l.}$). The atmospheric Čerenkov light produced by extensive air showers are collected by the 3.8m reflector and recorded by the imaging camera consisting of 256 photomultiplier tubes. A trigger pulse is produced when any 5 PMTs exceed 3 photoelectron level. The CANGAROO collaboration has observed targets in the southern hemisphere since 1992 (Hara et al., 1993).

The reflectivity of the CANGAROO 3.8m mirror was improved in October 1996 at the AAO (Anglo Australian Observatory), Coonabarabran. The reflectivity of the mirror increased from 45% to 90% after the recoating and the estimated energy threshold decreased to below 1TeV at zenith. Data shown here were taken both before and after this recoating work.

The total observation time for PSR1509-58 is shown in Table 1 and that for PSR1259-63 is shown in Table 2. The selected observation time under cloudless conditions is also shown. Because of the different energy threshold of observations before and after October 1996, as mentioned above, the data are summarized in two periods for PSR1509-58. Observations of these objects are continuing in 1997, in particular PSR1259-63 will be observed around the newest periastron (UT29.8 May97).

The analysis for the newest observations with lower energy threshold is in progress and results are presented at the conference. Here we show the preliminary results of analysis on PSR1509-58 (1996 data) and PSR1259-63 at the previous periastron.

PSR 1509 – 58

The gamma-ray pulsar PSR1509-58 has the fifth largest \dot{E}/d^2 among known radio pulsars and is the second youngest pulsar following the Crab. Pulsed gamma-ray emission from this object was detected by the BATSE and OSSE experiments with a 150msec pulsar period. Although it

Table 1: Total observation time for PSR1509-58. The selected observation time under cloudless conditions is also shown.

| Period | On Source | Off Source | On Source selected | Off Source selected |
|-----------------------|------------|------------|--------------------|---------------------|
| May June, 1996 | 55.2 hours | 52.5 hours | 52.5 hours | 50.5 hours |
| March April May, 1997 | 42.7 hours | 41.2 hours | 36.9 hours | 35.3 hours |

Table 2: Total observation time for PSR1259-63. The selected observation time under cloudless conditions is also shown. Two periastrons are included during the observation. One is January 9, 1994 and another is May 29, 1997.

| Period | On Source | Off Source | On Source selected | Off Source selected |
|--------------------|------------|------------|--------------------|---------------------|
| January 8–10, 1994 | 8.6 hours | 4.7 hours | 8.6 hours | 4.7 hours |
| May, 1994 | 29.5 hours | 24.5 hours | 26.5 hours | 19.1 hours |
| March, 1997 | 23.1 hours | 22.4 hours | 23.1 hours | 22.4 hours |
| April, 1997 | 5.6 hours | 2.6 hours | 4.8 hours | 2.6 hours |

has not been detected by the EGRET experiment (Fierro indicates a DC excess with 3 sigma level), recent X-ray observations have revealed energetic features around this pulsar. From early observations, a complicated structure of X-ray nebula has been known; the "south nebula" (SN) exists centered at the pulsar, and another "north nebula" (NN) at the supernova remnant MSH 15-52. Recent ASCA observation (Tamura et al. 1996) of X-ray line emission has clearly shown that SN is of non-thermal spectrum and NN of thermal origin, in addition, to find emission of a jet-like shape which connects these two nebulae. The magnetic field in the nebulae is estimated probably to be as weak as the interstellar value. Thus, the object is very likely a VHE gamma ray source, and it is interesting and important to locate which part of the system may emit inverse Compton VHE gamma rays. du Plessis et al. (1995) performed an observation with a 7 TeV energy threshold and set an upper limit for VHE gamma-ray emission before the discovery of the jet feature. Results of analysis for VHE gamma-ray emission from the pulsar position and studies looking for an emission offset from the pulsar position are presented.

Each Čerenkov image is fitted to an ellipse and image parameters, which are commonly used (e.g. Reynolds et al. 1993), are derived . After image selection no significant excess can be seen in the distribution of alpha parameter in the data of 1996. An estimation of the 3 σ flux upper limit from this preliminary result corresponds to

$$F(>3\text{TeV}) < 2 \times 10^{-12} \text{cm}^{-2}\text{s}^{-1}$$

In this calculation, the source is assumed to be point-like.

An analysis assuming the thermal nebula as a source has also been performed. No significant excess is found. This result will be compared with that obtained by the observation with a lower energy threshold in 1997.

PSR 1259 – 63

The binary pulsar PSR1259-63 has a high eccentricity of 0.8699 orbiting around a massive Be star (SS2883) companion with orbital period of 1236.72 days. Be stars are known to produce substantial gaseous outflows (e.g. Waters et al. 1988). It is possible that the interaction between this gaseous nebulae and the pulsar relativistic wind makes a shock in this system. Actually some experiments have shown the emission in X-ray to soft gamma-ray band near the

previous periastron (Hirayama et al. 1996, Tavani et al. 1994, Kaspi et al. 1995).

Gamma-ray signals were searched comparing alpha distribution between on-source events and off-source events. No significant gamma-ray signal was obtained during the previous periastron. On the contrary a 4.8σ excess was obtained from the data obtained 4 months after the periastron, although this result is preliminary. The gamma-ray flux is calculated preliminarily as

$$F(>3\text{TeV}) \sim 4.6 \times 10^{-12} \text{cm}^{-2}\text{s}^{-1}$$

Alpha distributions of the events in this period are shown in Fig. 1. These results will be compared with the newest results obtained in 1997 including the next periastron.

OTHER PULSARS AND DISCUSSIONS

The established VHE gamma-ray source PSR1706-44 was also observed in 1994 and 1995. The estimated flux from these new observations is consistent with the earlier result (Kifune et al. 1994). More observations will be performed in 1997 with a lower energy threshold.

There still remain a lot of studies of VHE gamma rays from pulsars and their associated supernova remnants as is the case for the EGRET galactic sources, most of which are still unidentified. Observations of the gamma-ray sky by the CANGAROO telescope, as well as by other Air Čerenkov Imaging Telescopes in the world, still play an important role, although future telescopes are planned and/or under construction.

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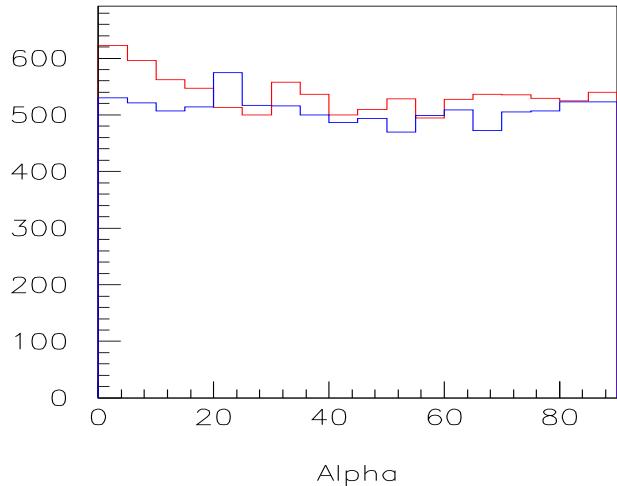


Fig. 1: Alpha distributions of events obtained 4 months after the periastron, January 9, 1994, of the PSR1259-63. The chain line is for on-source event and the solid line is for off-source events. Observation time of off-source events is normalized to that of on-source events.